PERFORMANCE
OF
BUBBLE DECK SLAB

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B. ENG (HONS.) CIVIL ENGINEERING

UNIVERSITI MALAYSIA PAHANG

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor Degree in Civil Engineering.

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Date : 11 JUNE 2018

STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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ABSTRAK

Struktur slab dianggap sebagai salah satu struktur terbesar yang menggunakan sejumlah besar konkrit dalam pembinaan bangunan. Konkrit adalah bahan tunggal yang paling banyak digunakan di dunia. Malangnya, konkrit mempunyai masalah [6]. Bahan-bahan konkrit yang dicipta akan mencemarkan alam sekitar. Pada tahun 1990-an, Jorgen Bruenig telah mencipta slab berongga biaxial yang pertama yang dipanggil slab gelembung dek. Sistem slab gelembung dek bertindak sebagai kaedah praktikal membuang jumlah konkrit dari tengah-tengah slab lantai kerana tidak melaksanakan sebarang tujuan struktur [1]. Oleh itu, ia mengurangkan berat mati struktur secara dramatik kerana jumlah signifikan konkrit telah 'dipindahkan'. Kekosongan di tengah-tengah slab rata dipenuhi dengan sfera plastik yang membuang slab berat diri. Secara mengagumkan, penyingkiran berat badan slab kira-kira hasil sebanyak 35% dalam mengurangkan sekatan beban mati yang tinggi dan span yang pendek [9]. Jumlah kuantiti konkrit yang dikurangkan telah mengakibatkan penurunan pengeluaran karbon dioksida secara tidak langsung dan dengan menggunakan plastik kitar semula sebagai bahan pengganti alternatif untuk sistem konkrit gelembung dek boleh dianggap sebagai kaedah pembinaan slab yang menyumbang kepada teknologi hijau. Prestasi papak gelembung gelung ditentukan dengan perbandingan dibuat terhadap papak konvensional yang berdasarkan kekuatan lenturan, jenis kegagalan dan corak retak dan penyebaran. Spesimen yang digunakan ialah 1500mm dengan 1500mm untuk lebar dan panjang dengan ketebalan 285mm. Sebanyak 25 gelembung plastik HDPE berongga ketebalan 230mm telah digunakan untuk spesimen gelembung dek. Besi tetulang keluli yang digunakan ialah tebal 6mm keluli hasil ringan. Tambahan pula, sebanyak 12 kiub konkrit dimensi 150 kubik mm dengan gred konkrit 30 dibahagikan kepada 4 jenis masa pengawetan konkrit dengan 3 setiap satu iaitu 3 hari, 7 hari, 14 hari dan 28 hari sebelum ujian mampatan dilakukan. Selain itu, ujian tegangan telah dijalankan untuk menghasilkan keluli yang tinggi bersaiz 8mm dan 10mm manakala keluli ringan adalah 6mm, 8mm dan 10mm. Ujian fleksural dilakukan pada kedua-dua slab gelembung dek dan slab konvensional dengan menggunakan tiga ujian lenturan titik selepas pengawetan kedua-dua slab dalam air selama 28 hari. Daripada keputusan yang diperoleh, penurunan kekuatan ricih sebanyak 53% untuk slab gelembung dek manakala 36% untuk slab pepejal konvensional dengan kekuatan ricih reka bentuk 136.64 kN. Kekuatan lenturan slab gelembung dek adalah 447.51 MPa yang lebih rendah daripada slab konvensional, 608.09 MPa. Ia dapat disimpulkan bahawa slab gelembung dek dengan berat badan yang lebih rendah dan dimensi yang sama berbanding dengan papak pepejal konvensional mempunyai beban muktamad yang lebih tinggi daripada papak pepejal konvensional. Selain itu, pada beban puncak, retakan utama dan mikro retakan berlaku di tepi berhampiran pertengahan slab.

ABSTRACT

Slab structure is considered as one of the largest structural members that consumes large amount of concrete in a building construction. Concrete is the single most widely used material in the world. Unfortunately, concrete has a problem [6]. Concrete created substances that polluted the environment. In the 1990's, Jorgen Bruenig had invented the first biaxial voided slab called bubble deck slab. Bubble deck slab system acts as a method of practically removing the concrete volume from the middle of a floor slab for not performing any structural purpose [1]. Thereby it reduces the structural dead weight dramatically as significant amount of concrete volume has been 'evacuated'. The voids in the middle of a flat slab are filled with plastic spheres that remove the self-weight of slab. Impressively, the removal of self-weight of the slab approximately result by 35% in removing the restriction of high dead loads and short spans [9]. The reduced amount of concrete volume has led to the decreasing production of carbon dioxide indirectly and by using recycled plastic as an alternative replacement material for concrete, bubble deck slab system can be considered as a slab construction method that contributes to green technology. The performance of bubble deck slab was determined with comparisons being made against the conventional solid slab which was based on the flexural strength, type of failures and the crack pattern and propagation. The specimens used were 1500mm by 1500mm for width and length with a thickness of 285mm. A total of 25 HDPE hollow plastic bubble balls of thickness 230mm were used for the bubble deck slab specimen. The reinforcement steel bar meshes used were 6mm thick of mild yield steel. Furthermore, a total of 12 concrete cubes of dimensions 150 cubic mm with concrete grade 30 were divided into 4 kinds of concrete curing periods with 3 each which were 3 days, 7 days, 14 days and 28 days before compression test was conducted. Apart from that, tensile test was carried out for high yield steel size 8mm and 10mm while mild steel are 6mm, 8mm and 10mm. Flexural test was done on both the bubble deck slab and conventional solid slab by the application of three point flexural testing after both slabs were cured by water for a total of 28 days. From the results obtained, the percentage drop of shear strength was 53% for bubble deck slab whilst 36% for conventional solid slab with comparison with design shear strength of 136.64 kN. The modulus of rupture of bubble deck slab was 447.51 MPa which was lower than conventional slab, 608.09 MPa. It can be concluded that bubble deck slab with lower self-weight and same dimensions as compared to conventional solid slab has a higher ultimate load than conventional solid slab. Moreover, at peak load, microcracking occurred at the sides near the middle of the slab.

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LIST OF SYMBOLS

^{o}c	Degree Celsius
E	Modulus of Elasticity
kN	Kilo Newton
mm	Millimetre
m	Metre
%	Percentage
kN/mm^2	Kilo Newton per millimetre square

LIST OF ABBREVIATIONS

HDPE	High Density Polyethylene
BD	BubbleDeck
OPC	Ordinary Portland Cement
UTM	Universal Testing Machine
LVDT	Linear Variable Differential Transformer
Eq.	Equation
et al	*et alia*

CHAPTER 1

INTRODUCTION

1.1 History Background

Slab structure is considered as one of the largest structural members that consumes large amount of concrete in a building construction (Bhade & Barelikar, 2016). Since it requires a big amount of concrete volume, it has to be designed in appropriate way. According to Bhade and Barelikar (2016), the deflection of the slab structure tends to increase as the concentrated load acting on the slab is great which leads to the expanding of slab thickness. The high thickness of slabs will create a heavier slab due to the increasing of self-weight of and also the size of column and foundations. In conclusion, the increase of size of structure members such as the beam and column will generally increase the total amount of materials used and consequently the cost increases as well.

In the mid-20th Century, the voided or hollow core floor system was created to reduce the high weight-to-strength ratio of typical concrete systems. This concept removes or replaces concrete from the centre of the slab, where it is less useful, with a lighter material in order to decrease the dead weight of the concrete floor. However, these hollow cavities significantly decrease the slabs resistance to shear and fire, thus reducing its structural integrity (Lai, 2010). Thus, there is a numerous number of researches continue to perform and conduct tests in order to overcome this problem especially to the design engineers in order to reduce the weight of the slab structure without affecting the structural integrity.

In the 1990's, Jorgen Bruenig had invented the first biaxial voided slab called bubble deck slab (Mirajkar *et al*, 2017). Bubble deck slab system acts as a method of practically removing the concrete volume from the middle of a floor slab for not performing any structural purpose as shown in Figure 1.1. Thereby it reduces the structural dead weight dramatically as significant amount of concrete volume has been 'evacuated'. Bubble deck slab is based on an established technique which involves the relationship between air and reinforcement steel bars. The voids in the middle of a flat slab are filled with plastic spheres that remove the self-weight of slab. Impressively, the removal of selfweight of the slab approximately result by 35% in removing the restriction of high dead loads and short spans (Teja *et al*., 2012).

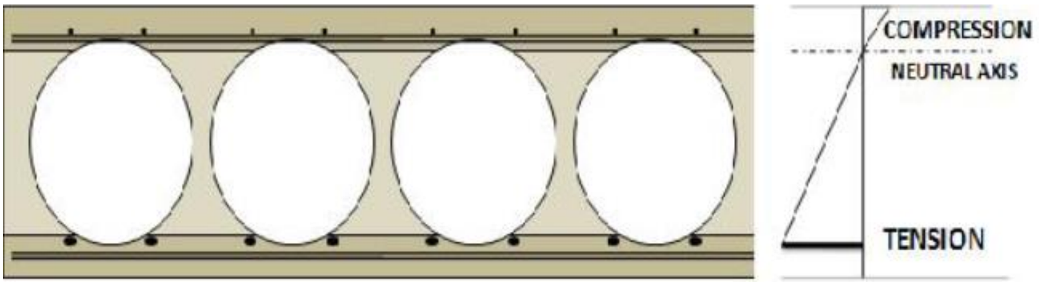

Figure 1.1 Stress diagram of bubble deck slab

Source: Teja *et al*. (2012)

Slab thickness can be reduced since the weight of the slab structure has greatly reduced. The lower weight or slab structural members results in lower load transfer to columns and ultimately the foundations. In other words, columns and foundations can be designed in smaller sized which also mean the overall construction costs can be reduced. Bubble deck slab, without the necessity of formwork practically, no support beams. In additiona, the fabrication of slab structures is roughly 20% faster than the method of conventional regardless of shape, complexity or the project size (Joseph, 2016).

The bubble deck creates void area of air between concrete layers top and bottom with reinforcement steel meshes and the load distribution across the plastic spheres. Bubble deck is a new innovative slab system that might not see any major differences in a building's construction at the beginning but in a –situ casting, the application of Bubble deck technology gives many significant differences.

The bubble deck system offers a wide range of advantages in building design and during construction. Numerous attributes that will consider the system as green technology are the usage of recycled materials such as the plastic spheres, the reduction of construction materials and energy consumption, the reduced amount of concrete, less transportation and less utilization of heavy machinery and crane lifts that make bubble deck a more environmentally friendly than other slab construction system techniques. According to Joseph (2016), bubble deck can achieve larger and longer spans as compared to a site cast concrete structure without the necessity for pre-stressing or post-tensioning components through the removal of ineffective concrete and replacing it with plastic spheres that greatly reduce the dead load of the structure. Through the method of prefabrication and in-situ casting, the total construction time for the structural members was reduced which allowed the design engineers to accelerate the design. The contractor is estimated to set roughly 5574 m^2 in a month and allowed the completion of concrete structure before the fall classes even started (Joseph, 2016).

1.2 Problem Statement

Concrete is the single most widely used material in the world. Unfortunately, concrete has a problem. Concrete has condemned through its application in innumerable architectural eyesores, from carparks to tower blocks, concrete's environmental credentials are now coming under scrutiny. The material is utilized globally that the production of cement worldwide now contributes 5 per cent of annual global carbon dioxide production, with China's booming construction industry producing 3 per cent alone (Crow, 2008). The problem is estimated to get worse where it has produced over 19.93 Tera Newton in quantity per year, it is predicted that the concrete use is to reach four times the 1990 level by 2050.

In a concrete slab structure, not all parts of the structural member are of maximum usefulness (Joseph, 2016). The central portion of the reinforced cement concrete solid slab is an inactive concrete as shown in Figure 1.2. The spacer between the bottom, where the reinforcing steel is in tension, and the top, where the concrete is in compression is inactive due to the lack of force. It would be a waste of concrete if the spacer is to be filled up with concrete. Concrete is heavy and it increases the dead loads of the structure. The spacer can be removed and replaced with lighter materials such as

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